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Lists of Species

True Mangrove Species of Sundarbans Delta, West Bengal, Eastern India

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Abstract: Varied opinions exist as to the species composition and ecological distinction of mangrove habitats of the Indian Sundarbans. Furthermore, distinction of true or major mangroves from mangrove-associate and minor species was left unresolved by past authors. The present study thus aimed to revise a species list of true mangroves in the Indian Sundarbans delta. An indexing of adaptive morpho-physiological characters of mangroves for the tidal-saline environment was conducted. The analysis illustrated 24 species of true mangroves in Indian Sundarbans, belonging to nine families. Of these, Rhizophoraceae showed maximum richness at each of the generic and specific categories assessed. The current study has highlighted the taxonomic richness and status of true mangrove from Indian Sundarbans, resolving the long debated distinction of true from minor and associate mangroves.

Introduction

The Sundarbans delta is a rich reservoir of flora and fauna due to its extremely dynamic physico-chemical factors. Encompassing India and Bangladesh, this highly dynamic zone supports a diverse gene pool of micro and macro biotic communities, in which mangrove vegetation occupies a special status (Guha Bakshi *et al.*, 1998). The Sundarbans mangrove ecosystem is highly productive and serves as a link between terrestrial and estuarine aquatic ecosystems (Untawale, 1987).

Mangroves are a threatened salt tolerant higher group of flowering plants (Naskar and Mandal, 1999) that occur in relatively sheltered areas along estuaries, coastal lagoons and backwaters. They are generally inundated and exposed during regular high and low tides respectively, and are nurtured by a mixture of fresh water from rains and land drainage with coastal marine waters (Banerjee *et al.* 2002). The plants of mangrove vegetation are relatively poor in species diversity and show similarities in their general architecture and physiological adaptations – a case of convergent evolution. Typical mangrove species usually have pneumatophores or breathing roots (negative geotropic root), stilt roots, knee roots, viviparous germination, xerophyllous leaves and salt excretory glands (Tomlinson, 1986). However, several mangrove workers like Mac Nae (1968), Blasco (1977), Mepham and Mepham (1984), Tomlinson (1986), Naskar and Guha Bakshi (1987) defined mangroves emphasizing on different eco-physiological attributes. Different approaches were adopted in the process towards classifying the mangrove species in different mangrove areas of India, including the Indian Sundarbans delta.

Regarding the species composition and ecological distinction of mangrove flora in the Indian Sundarbans, several authors opined variedly; viz. 60 species under 41 genera and 29 families (Rao 1986), 56 species of euryhaline mangrove and mangrove associates (Naskar and Guha Bakshi 1987) and 69 species under 49 genera and 35 families Mandal and Naskar (2008). Further ambiguity exists regarding the distinction of major or true mangroves from minor and mangrove-associated species, particularly at their generic levels. Mandal and Nandi (1989) reported 22 true mangroves species from Indian Sundarbans, while Chaudhuri and Choudhury (1994) reported 36 species. The studies of Naskar (1983) and Naskar and Mandal (1999) did not clarify this issue, as they remained uncertain regarding the exact status and composition of true or major mangroves in Indian Sundarbans. However, according to recent studies by Mandal and Naskar (2008), 28 species of major mangroves have been found in Indian Sundarbans. The study also mentioned Indian Sundarbans to be more diverse in its species composition than the other mangrove formations in India.

In the present context, the authors seek to revise the species list of the true or major mangroves occurring in Indian Sundarbans, taking into consideration their morpho-physiological characters for adapting to the tidal-saline environment in this deltaic region.

Materials and Methods

Study Area

The Indian Sundarbans (21°31′00″ N - 22°30′00″ N, 88°10′00″ E - 89°51′00″ E) is located on the southern fringe on the state of West Bengal spreading over the major portion of the districts of North 24-Parganas and South 24-Parganas. The region is bordered by Harinbhanga-Raimangal river along the International boundary with Bangladesh in the east, the Hooghly River in the west, "Dampier- Hodges line" in the North and Bay of Bengal in the south. The Indian Sundarbans delta (declared as Sundarbans Biosphere Reserve under the 'Man and Biosphere Programme' in 1989) covers an area of 9,630 km^2 (Naskar and Mandal 1999) (Figure 1). Of the 102 islands in the estuary, 54 are inhabited and the rest of the islands support mangrove forests (Chaudhuri and Choudhury 1994). The mangrove forests of the Indian

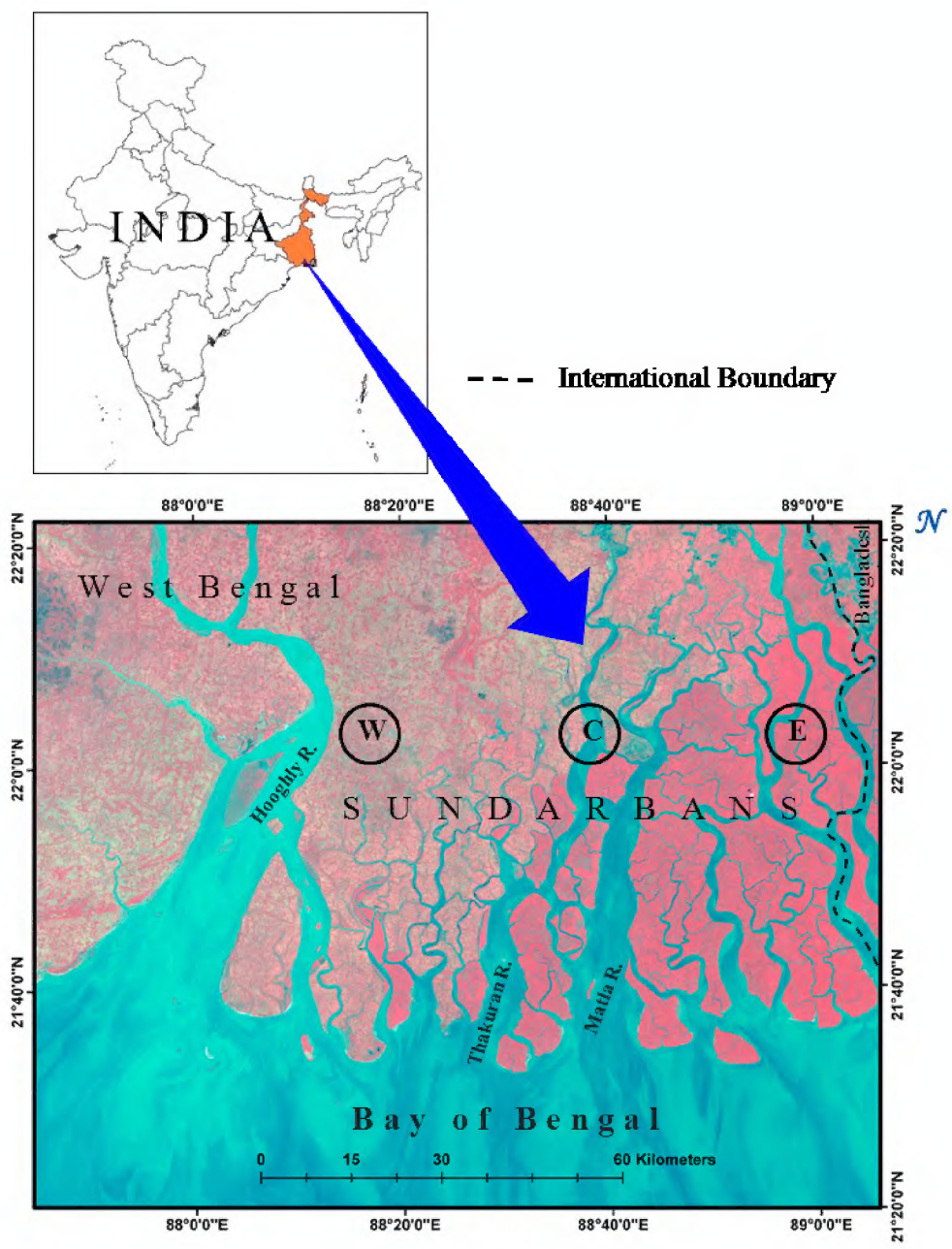

FIGURE 1. A satellite image of India Sundarbans; W, C and E represent Western, Central and Eastern parts of Indian Sundarbans under the present study.

Sundarbans have been estimated between 418, 888 ha. (UNEP 1985 (unpublished data)), 200,000-300,000 ha. (IUCN 1989) and 6,749 km^2 (Naskar and Mandal 1999). The discrepancy in the figures for forest cover possibly arises from the fact that some analyses denote areas designated as forest lands (*e.g.* including waterways and degraded forest) while others represent an assessment of the tree-covered areas only (Chaudhuri and Choudhury 1994).

Methodology

The present work is a species list for the true mangroves in Indian Sundarbans, following a set of morpho-physiological features (Figure 2) as regard their adaptation in the saline-tidal zone. The authors incorporated both the previous works (as literature survey) as well as field surveys. Field surveys for two years: 2010 and 2011 involved sampling of mangrove flora in Eastern, Central and Western parts of the Sundarbans (Figure 1), taking into account the adaptive features considered in the present case for being true mangroves. The adaptive features considered here were followed after Tomlinson (1986). Voucher specimens were deposited in the Centre for Biodiversity and Ecological Studies, India. Identifications were carried out at the specific category by the authors in consultation with various mangrove specialists. IUCN statuses were taken from the IUCN Red List of Threatened Species, Version 2011.2 (2012).

Fill Colour Abbreviations: Always Present; Occasionally Present; Absent

Name of Species	Woody Plants	Salt Excretory System	Succulent Leaves	Snake Roots	Viviparous germination	Pneumatophore	Root Buttress	Stilt Roots	Knee Roots
Bruguiera cylindrica	Always Present	Always Present	Always Present	Occasionally Present	Always Present	Absent	Always Present	Always Present	Absent
Bruguiera gymnorhiza	Always Present	Always Present	Always Present	Occasionally Present	Always Present	Occasionally Present	Always Present	Always Present	Always Present
Bruguiera parviflora	Always Present	Always Present	Always Present	Occasionally Present	Always Present	Absent	Always Present	Always Present	Absent
Bruguiera sexangula	Always Present	Always Present	Always Present	Occasionally Present	Always Present	Absent	Always Present	Always Present	Absent
Ceriops decandra/roxburghiana	Always Present	Always Present	Always Present	Always Present	Always Present	Absent	Always Present	Always Present	Always Present
Ceriops tagal/candolleana	Always Present	Always Present	Always Present	Always Present	Always Present	Absent	Always Present	Always Present	Always Present
Rhizophora apiculata/conjugata	Always Present	Always Present	Always Present	Absent	Always Present	Absent	Absent	Always Present	Absent
Rhizophora mucronata	Always Present	Always Present	Always Present	Absent	Always Present	Absent	Absent	Always Present	Absent
Kandelia candel	Always Present	Always Present	Always Present	Always Present	Always Present	Absent	Always Present	Always Present	Absent
Sonneratia apetala	Always Present	Always Present	Always Present	Always Present	Absent	Always Present	Absent	Absent	Absent
Sonneratia caseolaris	Always Present	Always Present	Always Present	Absent	Absent	Always Present	Absent	Absent	Absent
Sonneratia griffithii	Always Present	Always Present	Always Present	Absent	Absent	Always Present	Absent	Absent	Absent
Lumnitzera racemosa	Always Present	Always Present	Always Present	Always Present	Always Present	Always Present	Absent	Absent	Absent
Xylocarpus granthum/carapa	Always Present	Always Present	Always Present	Always Present	Absent	Always Present	Always Present	Absent	Always Present
Xylocarpus mekongensis	Always Present	Always Present	Always Present	Always Present	Absent	Always Present	Always Present	Absent	Always Present
Aglaia cuculata	Always Present	Always Present	Always Present	Always Present	Absent	Always Present	Always Present	Absent	Absent
Avicennia alba	Always Present	Always Present	Always Present	Always Present	Absent	Always Present	Absent	Occasionally Present	Absent
Avicennia marina	Always Present	Always Present	Always Present	Always Present	Absent	Always Present	Absent	Occasionally Present	Absent
Avicennia officinalis	Always Present	Always Present	Always Present	Always Present	Absent	Always Present	Absent	Occasionally Present	Absent
Aegialitis rotundifolia	Always Present	Always Present	Always Present	Always Present	Always Present	Absent	Absent	Absent	Absent
Heritiera fomes	Always Present	Always Present	Always Present	Always Present	Absent	Always Present	Always Present	Absent	Absent
Aegiceras corniculatum	Always Present	Always Present	Always Present	Always Present	Always Present	Absent	Absent	Absent	Absent
Nypa fruticans	Always Present	Always Present	Absent	Always Present	Always Present	Absent	Absent	Absent	Absent
Phoenix paludosa	Always Present	Always Present	Absent	Absent	Absent	Always Present	Absent	Absent	Absent

FIGURE 2. Consideration of key morpho-physiological features for being true or major mangroves, with a list of species qualifying for major counterparts of Indian Sundarban mangroves. The list of species follows the same order as in Table 1.

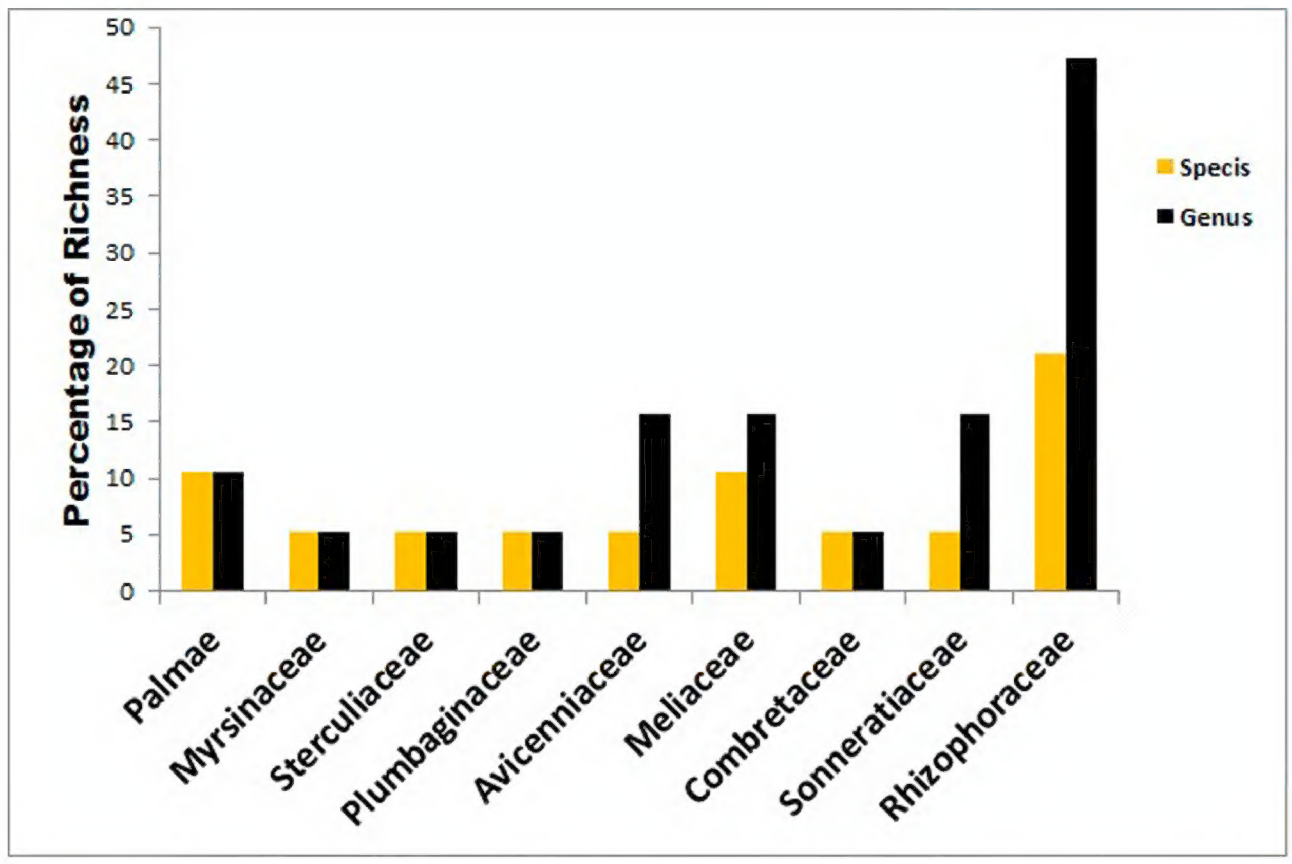

FIGURE 3. Graphical representation of the percentage of richness in genera and species of mangrove families in Indian Sundarbans pertaining to true mangroves.

RESULTS

Following the literature review and field survey, a total of 24 species of true or major mangroves were recorded in the Indian Sundarbans (Table 1 and Figure 2). The present species list comprises of nine species in four genera belonging to Rhizophoraceae family; three species in one genus to Sonneratiaceae; three species in one genus under Avicenniaceae; three species in two genera under Meliaceae; two species in two genera under Palmae/Arecaceae; and one species in one genus each under Combretaceae, Plumbaginaceae, Sterculiaceae and Myrcenaceae (Figure 3).

As the present article deals with species-level taxa of true mangroves in Indian Sundarbans, varieties of *Avicennia marina* Vierh., viz. *A. marina* var. *marina* (Forsk. Vierh) and *A. marina* var. *acutissima* Stapf. & Mold. ex Mold., as proposed by Naskar and Mandal (1999) were hence excluded from the species list. *Excoecaria agallocha* Linn., a widely noted mangrove-associate or even a marginal species (Askornkeae *et al.* 1992) that has been included under the true mangroves by Mandal and Nandi (1989) and Naskar and Mandal (1999) has also been excluded in the present study. Besides, considering the salient characters (for being true mangroves) adopted here (Figures 2, 4 and 5), *E. agallocha* qualified only for two characters, by being woody in nature and having snake roots, which seemed inadequate to meet the criteria for being true mangroves, as also suggested by Askornkeae *et al*. (1992). Likewise, *Porteresia coarctata* (Roxb.) Takeoka, *Acanthus ilicifolius* (L.), *A. volubilis* Wall. and *Scyphiphora hydrophyllacea* Gaertn. F. are also mentioned as true mangroves by Mandal and Naskar (2008), but are here also excluded from the present list as they too did not qualify for most of the aforementioned characters. All these species, however, were found to have salt-tolerant mechanisms, but as mangrove-associates (Giesen *et al.* 2006; Sengupta and Lahiri Majumdar 2010).

Of the nine families in Sundarbans, Rhizophoraceae shows the maximum richness in taxa at both genus and species level (Figure 3); this family, often referred to as the "true mangrove family" (Duke *et al*. 1998), shows the richest assemblage in most of the mangrove ecosystems of the world by having a myriad of adaptive specializations, as also evident in the present case of Sundarbans ecosystem (Figure 2). Features like stilt roots (Figure 5F) and viviparous germination in members of Rhizophoraceae in Sundarbans provide mechanical support towards substrate instability as well as increased survivability of saplings.

DISCUSSION

Mangrove ecosystems are threatened globally due to their widespread resources which are utilized for human use. In the Asia-Pacific region, non-sustainable utilization, overexploitation of resources and conversion to other land-uses principally for fish ponds, human settlements, infrastructure development and paddy cultivation are drastically reducing these resource bases at a very alarming rate (Umali *et al.* 1987). In Indian Sundarbans, the principal problems hindering sustainable management of the mangrove ecosystem is land acquisition by reclamation for settlement and expansion of agriculture resulting from population pressure (Burbridge 1984 (unpublished data)). Of the twenty-four true mangrove species in Sundarbans, five species are globally considered important regarding their conservation importance (IUCN, 2011). While *Sonneratia griffithii* Kurz. is critically endangered, *Heritiera fomes* Buch. Ham. (locally revered and called as Sundari) is considered endangered. The remaining three species, viz. *Ceriops decandra* Ding Hou, *Aegialitis rotundifolia* Roxb. and *Phoenix paludosa* Roxb. are near threatened. *Sonneratia caseolaris* Engler, however has not yet been enlisted in IUCN Red List (IUCN, 2011). The present study has illustrated an indexing system, and highlighted how the long debated distinction of true or major mangroves from minor and mangrove-associate species can be determined on common adaptive characters. It may further help in preparing or revising species lists of different mangroves, which in turn can support development of policy towards mangrove conservation in India.

Figure 4. The mangrove forest of Indian Sundarbans, showing the woody nature of the true mangrove plants.

Table 1. A list of true mangrove species from Indian Sundarbans Region with their IUCN status.

FAMILY	GENUS	SPECIES	VOUCHER NO.	IUCN STATUS
Rhizophoraceae	*Bruguiera*	*cylindrica* Blume	CBES403	Least Concern
		gymnorhiza Lamk.	CBES456	Least Concern
		parviflora Wt. and Arn.	CBES459	Least Concern
		sexangula Poir	CBES460	Least Concern
	Ceriops	*decandra* Ding Hou /*roxburghiana* Arn.	CBES471	Near Threatened
		tagal Robinson/*candolleana* Robinson	CBES472	Least Concern
	Rhizophora	*apiculata* Blume/*conjugata* Arn.	CBES507	Least Concern
		mucronata Lamk.	CBES549	Least Concern
	Kandelia	*candel* Druce	CBES664	Least Concern
Sonneratiaceae	*Sonneratia*	*apetala* Buch. Ham.	CBES692	Least Concern
		caseolaris Engler	CBES598	Not Listed
		griffithii Kurz.	CBES538	Critically Endangered
Combretaceae	*Lumnitzera*	*racemosa* Willd.	CBES612	Least Concern
Meliaceae	*Xylocarpus*	*granatum* Koen	CBES588	Least Concern
		mekongensis Pieree	CBES476	Least Concern
	Aglaia	*cuculata* Pellegrin	CBES440	Data Deficient
Avicenniaceae	*Avicennia*	*alba* Blume	CBES518	Least Concern
		marina vierh.	CBES432	Least Concern
		officinalis L.	CBES504	Least Concern
Plumbaginaceae	*Aegialitis*	*rotundifolia* Roxb.	CBES621	Near Threatened
Sterculiaceae	*Heritiera*	*fomes* Buch. Ham.	CBES556	Endangered
Myrsinaceae	*Aegiceras*	*corniculatum* Blanco	CBES484	Least Concern
Palmae/Arecaceae	*Nypa*	*fruticans* Wumb.	CBES579	Least Concern
	Phoenix	*paludosa* Roxb.	CBES614	Near Threatened

Figure 5. Representative images of adaptive features for true mangroves in Indian Sundarbans: (a) Succulent leaves of *Bruguiera sexangula*, (b) Salt crystals on the leaf of *Aegialitis rotundifolia*, (c) Viviparous germination in *A. rotundifolia*, (d) Pneumatophores in *Avicennia officinalis*, (e) Knee roots in *Xylocarpus mekongensis*, (f) Stilt roots in *Rhizophora mucronata*, (g) Snake roots in *Ceriops decandra*, (h) Root buttress in *X. mekongensis*.

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